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Method for short-cyclic data capture, for energy monitoring and for system control in the smart metering/smart grid using a piece of distributed, intelligent middleware

5 The invention relates to a method for short-cyclic data capture, energy monitoring and system control in smart metering/smart grid by using intelligent, distributed middleware.

10 A standard power grid has a centralised structure. The power in this grid topology is mostly generated by a small number of large power stations and is distributed unidirectionally to the end consumer. With increasing environmental awareness the amount of renewable energy in power grids, such as wind and solar power, is also increasing. However, the availability of wind and solar power fluctuates and thus cannot be planned for. In addition, renewable energy is generally generated at different
15 locations in smaller units over the whole power grid. The modern electrical grid is thus becoming more complex, less homogenous and is highly distributed in terms of energy production. An ideal balance between power generation, distribution and consumption would be achieved with regard to energy efficiency if:

1. power is only generated when it is used and if
- 20 2. only as much power is generated as required and
3. if it is generated exactly at the location where it is needed.

Unless it was possible to store sufficient amounts of electric power. However, this is not the case. It is not currently possible to store electric power in a satisfactory manner. In
25 order to meet the new requirements for energy efficiency, power grids have to be more intelligent in the future: "smart grid". They need to be able to provide in short cycles (promptly) a bidirectional flow of load and information between all central and decentral fossil and renewable power generators, grid components, storage facilities and consumers. In this way it is possible to achieve a coordinated cost-efficient energy
30 sector. The future means having an intelligent power and communication grid with distributed energy resources.

The increase in energy efficiency applies to power plant operators and equally to production and households, which are increasingly becoming distributed energy producers. For this it is necessary to provide suitable power monitoring and control systems.

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WO 2009/048963 A1 discloses a system for the intelligent web-based monitoring and management of an electrical system. The system comprises a data detection component, to which a sensor is connected which detects real time data, which is output by the electrical system and a web application server, which is coupled to the data detection component and is configured to send a user interface to a client terminal. The web application server has a virtual system model database, which is coupled to the data detection component and generates a virtual system model of the electrical system, a power analysis simulation machine with a virtual system-modulation machine which produces data for the electrical system by using the virtual system model of the electrical system and an analytics machine coupled to the virtual system model database.

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WO 2010/077830 A2 relates to the management of power outages and error statuses, in that information on events is received and is assigned to different devices within a power grid. Based on the information on events a status is determined for the various devices. It is established whether a failure condition is assigned to a specific device. For this an error intelligence application is used which receives synchrophasor data for each phase in a multiphase power grid. The synchrophasor has a phasor measurement and phasor angle information for each phase. The error intelligence application determines on the basis of the synchrophasor data the presence of an error in one or more of the phases and identifies a specific error type.

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EP 2 026 299 A1 describes an intermediate switching device which is connected between an intelligent electricity meter and a power consumer, wherein the power consumer has fluctuating power consumption, which is dependent on the type and the usage behaviour of the power consumer and thus forms an informative current signature. Thus from a measurement of the power consumption it is possible to determine the type and/or the usage behaviour of the power consumer. The

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Intermediate switching device obscures the connection between the power consumption of the consumer measured by the electricity meter on the one hand and the type and/or the usage behaviour of the power consumer on the other hand, in order to conceal the informative current signature of the power consumer and thereby make it more difficult to spy on an analysis of the current.

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EP 1 887 743 A1 discloses a method and a system for the adaptive processing of the quality of a service from interactions between intelligent networks and company applications by using a middleware message-routing machine.

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US 6,785,592 B1 discloses a method and a device for forecasting the energy consumption of an industrial production plant, in which production volumes planned for a forecasting period are entered as input data into a neural network and energy consumption is determined for the forecasting period as output data from the neural network. The neural network is trained using known historic input and output data, wherein the amount of historic input data is reduced by forming weighted sums of input data for determining weighting factors for the formation of the weighted sums an optimisation problem with a predefined target condition is formulated and from the known connections, according to which output data results from the input data firstly an equation system with weighting factors is set as a variable. Afterwards the weighting factors are determined again as a function of the target condition for deviations of the output data calculated from the most recently determined weighting factors.

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US 2009/267792 A1 describes a method for performing an automatic meter reading in a grid with a plurality of devices for automatic meter reading or nodes at customer locations, wherein a plurality of access points in the grid using selected service customer locations, wherein the associated customers are workers of an application, and by using additionally selected service customer locations, wherein the associated customers are not workers of the application, and is implemented by using service constructed locations. Said access points are coupled to a global communication network, by selecting a plurality of customer nodes for providing a portion of the co-localised access points at their meter installation points, recruitment and use of a plurality of service workers who are customers, in order to provide a worker-supported portion of the

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combined access points to their meter installation points, recruitment and use of a plurality of non-worker customers for providing a portion of the combined access points at their meter installation points and provision and use of a plurality of service-controlled locations which form a subsection of the access points. Furthermore, the
5 known method includes determining the use of goods with the devices for an automatic meter reading and the transmission of the data on the use of goods from the customer devices for an automatic meter reading through the grid via access points and by hopping the data from one node to another node in the network, receding the data at a node, which has a co-localised access point, feeding said data into the global
10 communication grid via the common access point and receiving the data on the service via the global communication grid.

WO 2006/055334 A1 discloses a method and a system for controlling the temperature in a building. For this purpose data detected in the building is received by a local processor,
15 which data is assigned to the temperature in the building, the weather outside the building and/or the occupants of the building. The received detected data is compared by the local processor with corresponding forecast data relating to the temperature in the building, the weather outside the building and/or the occupants of the building.

20 The invention proposes a method for the distributed, intelligent, short-cyclic data capture and system control of a large number of measurement points according to the requirements of an intelligent power supply grid, in which

- a plurality of servers distributed in the power supply grid are used, which together form a middleware,
- 25 - by means of the middleware, by using a middleware interface, measurement values (MW) of digital measurement devices and meter readings (ZW) are captured in short cycles and the digital measurement devices as well as additional sensors and actuators are controlled,
- the measurement devices are combined into groups which are assigned respectively to
30 a server, tariff information (TR) in the middleware is assigned to the measurement values (MW), wherein the middleware interface is responsible for providing the meter readings (ZW) and forwarding superordinate control signals and the short cyclical data capture means capturing measurement values in a time interval from 20 ms to 5 s

depending on the network size of 1,000 to several 10,000s of terminals and depending on the capacity of the digital measuring devices,

- the measurement values (MW) and the meter readings (ZW) in the middleware are subjected to a validation check by signature verification (SV),

5 - an image of the state of the power supply grid in memory variables (HD) and a raw value memory in the middleware is provided cyclically and time stamps are added automatically,

- the measurement values (MW) in anonymised form are linked to a meter identification in the middleware by internal middleware services (MD),

10 - an anonymisation of meter readings (ZW) by replacing the description of the measurement value jump (e.g. device identification) is performed by means of an anonymisation middleware service (A-MD),

- a middleware service (MD) is responsible for assigning the measurement values (MW) to terminals and an assignment ensures that the meter reading (ZW) of a terminal

15 always remains reconstructible,

- the data capture and the control of internal middleware services (MD) are performed in the middleware,

- the servers are connected to one another via a communications network and communicate via internal network interfaces so that the measurement values and the

20 meter readings are available at each server,

- the communication with the digital measuring devices is performed according to a protocol defined by a smart measuring device (S-MG) or lean measuring device (L-MG)

and the middleware interface is used for communication, wherein a smart measuring device (S-MG) has intelligence and is designed for pre-processing the measurement

25 values (MW), whereas a lean measuring device (L-MG) does not have any intelligence and is only designed for outputting unprocessed measurement values (MW),

- for lean measuring devices (L-MG) the link between meter readings (ZW) and tariff information (TR) is performed by a middleware service (S-MD),

- for smart measuring devices (S-MG) the link between tariff information (TR) is ensured

30 by the device and

- a further middleware service (L-MD) controls a corresponding tariff structure (TRS) of the device and performs the synchronisation of an integrated clock.

Preferred embodiments and developments of the invention are described in the dependent claims.

5 The method described here makes it possible to implement IT infrastructures which ensure short-cycle and bidirectional data and event transmissions and by means of which energy efficiency concepts can be implemented effectively in the "smart grid" and also in production (green production) and in households (green house).

10 The proposed method is characterised in that it distributes intelligence into the information infrastructure of the "smart grid" as distributed middleware, if necessary locally. In this way it can be adjusted optimally to an existing power grid topology and distributed accordingly (clustering). The distributed middleware is able to detect in short cycles (promptly) by means of digital meters with end consumers and additional sensors the state of the respective energy grid cluster.

15 The distributed middleware after the data capture then either initiates a corresponding optimisation strategy itself, for example for controlling the energy flow, or retrieves the optimisation from a superordinate application (App). Each intelligent node of the middleware can be in the form of a low-resource system (embedded system) and
20 configured to be dynamic and flexible.

Middleware generally consists of a data infrastructure and normally represents a level in a software system, which enables the exchange of data and the transmission of events between individual software components (applications - apps). By means of the
25 middleware software components (apps) with different architectures (data formats, programming languages, operating systems, topologies) can be connected to one another.

30 The middleware includes uniform and comprehensive methods for defining data and events. Each software component/ application (app) has an interface for connecting to the middleware. The job of the interface is to convert application-specific semantics into middleware definitions and vice versa. The middleware is located on layer 7 of the ISO/OSI level model and does not work generally on the field level.

Most often network protocols are used for communication which are based on TCP/IP (Transmission Control Protocol/internet Protocol) or UDP (User Datagram Protocol), which are also supported by most office applications. The communication runs
5 bidirectionally for each interface, i.e. applications (apps) can only send and receive the data via a single interface.

A smart grid/ smart meter refers to an intelligent energy infrastructure, which is intended to deliver electrical energy according to the current need, or regulate the
10 current requirement as a function of the current energy supply. This is performed by means of a complex system of managing and controlling energy production plants, storage facilities and consumers, so that there is always an equilibrium between the delivery and use of the electric energy. For this purpose, it is necessary to detect the current network statuses in a timely manner. This means that throughout the whole
15 power grid, particularly at important node points, a plurality of sensors and actuators are installed. Creating an image of the network status in a widely distributed network means selectively capturing, distributing, structuring and presenting a large amount of data. For this purpose a high-performance communication network is necessary. The topology of this network should be designed to be flexible in terms of area and time,
20 whereby a network-independent identification of the sensors and actuators is necessary.

For the detection of additional network data digital meters such as intelligent electricity meters, also referred to as smart meters, are installed into individual households. The
25 latter consist of measuring devices which digitally capture the consumption or production levels and make them available via communication interfaces. Through the interfaces said meters are also integrated into the dynamic communication network. For data protection reasons information from digital meters is transmitted in an encrypted or anonymised form. The signing of measurement values is intended to ensure the
30 accuracy of the data. In the following for marking digital meters for electrical power in addition to smart meters also **smart metering devices (S-MG)** are used. The term lean meter (L-MG) is also used which is another variant of a digital metering device.

Previously the capture of data by smart metering devices (S-MG) has been performed by energy utility companies (EVU) or meter operators (MSB) mostly for only several hundred devices for invoicing special contract customers. Said customers have such a high consumption of energy that they are entitled to monthly billing and to the provision of their consumption data at 15 min intervals.

With individual software installed on a central server and suitable software modules for digital meters installed with customers static data and data saved in the device are detected. Only the conditions that exist at the time of the reading can be captured.

In individual cases middleware can also be used. The latter consists of central middleware which only runs on a node or server. This results in restricted scalability.

Typically the data capture is only performed once a day according to a programmed timetable or manual command. It has to be checked regularly by the user. The measurement values are then saved by the software in an integrated or external database and made available to the customer monthly by the energy utility company (EVU) or meter operator (MSB).

With each data reading a point-to-point connection is created to each device consecutively, or in a small number of cases also in parallel, which transmit measurement values saved in the metering device at an interval from the last reading and then the connection is cut off again.

Communication is often performed in conventional readout systems via GSM (Global System for Mobile Communication) using the GPRS protocol (General Packet Radio Service) - use of the mobile network. Other modes of transmission include PLC (Powerline Communication) – use of the existing power grid - or proprietary wireless networks.

The energy market is facing new challenges relating to requirements defined by smart grids/ smart metering devices. The estimated amount of fluctuating energy inputs, taking into account cogeneration plants, in the power grid will increase in the coming 10

years by about 40 %. The topologies of the energy networks therefore have to be restructured and redesigned. There is a urgent requirement to integrate the fluctuating energy successfully. Energy transfer, load management and not least transaction mangement have to be reregulated in parallel to this. The consumer/ producer

5 behaviour of households, workshops and small and medium-sized businesses will be significant with regard to increasing the energy efficiency in the smart grid/ smart metering system. The internet and broadband IT infrastructures of energy suppliers or meter operators are and have to be consulted in order to handle the new tasks. An important problem is the short-cycle mass data capture of several thousand energy

10 measuring devices (practically in real time). For this reason an efficient IT infrastructure is necessary with new properties, as described here in the method. The short-cycle captured data makes a large contribution to improving the load management (short-cycle evaluation of energy flows, cable data and status data), for extending the application management with regard to the introduction of new methods and products

15 for data analysis, for energy generation, distribution and optimisation. The introduction of new methods to the customer relationship and invoicing is then almost inevitable. Of particular importance here is the short-cycle interaction with the new generation of energy-conscious consumers / producers (ProSumern). The consumer/ producer will be consulted continuously with the aim of optimising their own energy consumption, if

20 they are also given the oppportunity to match their short-cycle load profile with current tariffs.

The current energy grid is extremely heterogeneous. This means it consists of a plurality of different installation parts, software and hardware components. The latter have

25 different years of construction and are from different manufacturers etc. In addition, due to the increase in decentral, mostly regenerative energy sources, the energy grid has even more decentral properties of a locally distributed system.

The future short-cycle captured data can be made usable for the following applications:

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- representation and analysis in SCADA systems (Supervisory Control and Data Acquisition).

In order keep the combination of energy production and energy consumption in a state of equilibrium, this relates in particular to the fluctuating energy to be incorporated (from renewable sources such as solar and wind power), it is necessary to be able to acquire data in a short-cycle in addition to the existing long-cycle capture of characteristic data. The provision of this additional data provides further degrees of freedom in the SCADA system for the superordinate load management.

- *Local load flow optimisation*

Energy production and energy requirements in the immediate neighbourhood should be identified in the smart grid and are compensated by means of local load optimisation methods. Here it is also possible to use self-organising systems. For this purpose, identification data is identified from the grid, the quality of which is dependent on the time resolution (short cyclical) of the measurement data acquisition.

- Use for energy purchase.

The provision of short-cycle measurement data can signify competitive advantages in the energy business.

- Representation in the customer portal

If customers are provided online with the short-cycle measurement data of their smart meters, their interest in their own energy consumption will be much higher than with static day values. Each change in energy use in the household is detected and can be represented immediately in a suitable form.

The middleware used in the method is configured for the requirements in the intelligent power grid "smart grid" and developed accordingly. The capture of grid data is performed short-cyclically, and not at the usual 15 min intervals. In this case short cyclically means the capture of measurement values in a time interval of 20 ms to 5 s for grid sizes of 1,000 to several 10,000 terminals.

The new method uses an distributed intelligent middleware in the smart grid. According to Fig. 1 the middleware has a software level between the application level and the measuring and control level. In the measuring and control level the data detection is performed of smart (S-MG) to lean (L-MG) digital meters. The intelligence for performing smart grid functions is implemented in the distributed middleware. It is thus available in each distributed network node. It can work in an embedded system architecture (computer with low energy and memory requirement). The middleware is designed to be independent of the operating system and hardware. It can if necessary be integrated as infrastructure (resource, performance and energy optimal) into the meters (S-MG or L-MG).

An example of the structure of the whole system for use in a smart grid/ smart meter with distributed middleware is illustrated in Fig. 1 and explained in more detail in the following.

On the upper side there is the application level with an extract of the different applications (apps) in a smart grid/ smart meter. The SCADA (*Supervisory Control and Data Acquisition* - system for energy grid monitoring and control), CRM (*Customer Relationship Management* – management system for customer data and relationships), billing (invoicing system), EDM (energy data management system - system for processing data for energy supply and energy use, a customer portal (internet portal for viewing invoices, consumption and production data for customers) and a meter management system are also located here. On the lower side is the measuring and control level with the meters (S-MG for smart metering device/ L-MG for lean metering device). Likewise a metering database is located there which contains the standardised and measurement device independent data of the different devices. The middleware lies as a level between the application level and measurement and control level.

The distributed intelligent middleware LabMap is shown which consists of two nodes and is connected via the internal communication interface LabNet. Within the middleware there are intelligent middleware services (I-MD), which can take over jobs in the form of smart grid/ smart meter problems, such as data reduction and clustering.

Interfaces connect the middleware to the applications (apps) in the application level and the meters (MG) in the measuring and control level.

5 Current methods are set up centrally and implement the necessary intelligence for managing the problems of the smart grid/ smart meter either in the application level or in the measuring and control level. If necessary there is also a weighting of intelligence between these two levels. The IT infrastructure in between is only used for simple data communication.

10 The distributed intelligent middleware takes over the jobs to be performed in the form of configurable intelligent middleware services (I-MD). The application level is thereby relieved and allows a simplification and thus a broad standardisation of applications (apps) in the application level. Said middleware services comprise for example:

- 15
- middleware service for the anonymisation of data (A-MD)
 - smart middleware service (S-MD) for processing a lean meter
 - lean middleware service (L-MD) for processing a smart meter
 - local optimisation middleware service (LO-MD) for local data optimisation in the distributed intelligent middleware by forming "virtual households" and "virtual
- 20 power stations"
- general and additional middleware services (MD)

By means of the distribution of the intelligent middleware intelligent nodes distributed locally in the whole grid are formed. In this way a needs-based, flexible, virtual,

25 collective intelligent network topology can be created.

With the large and increasing number of smart meters scalability is an important issue. This includes the ability to expand a system further without making major changes to the architecture.

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In order to avoid having large servers the middleware is designed to be distributed. In this case smart meters can be combined into functional groups or groups of terminals (EG) which are managed respectively by a middleware node (concentrator). A functional

group is for example a specific number of energy consumers/ decentral energy producers, represented by the installed digital meters. The distribution of the middleware can be oriented for example to the topology of the communication networks. In addition, the functions in the whole system, which need not be continually available, can be distributed so that individual nodes are only responsible for said functions. This enables the temporary deactivation of said nodes in terms of "green IT". If there are requirements for functional groups with respect to the short-cycle (e.g. 1,000 smart meters are to be queried in a cycle of 1 s), the middleware can be tailored to said performance requirements.

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The use of middleware embedded allows the use of low-resource systems and systems adapted precisely to the application.

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The use of middleware embedded enables the implementation of functions of smart metering in intelligent nodes on site, instead of central servers. Then a plurality of sensors and actuators can be managed from an intelligent node. The terminals in the smart grid are for example domestic and industrial smart meters, MUC devices (Multi-utility Communication), components of switchboards and network stations, charging stations for electromobility and others. The data is detected, processed, analysed, transmitted on site and is used if necessary for an automatic regulation and control function.

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The known relief of applications by the intelligent distributed middleware is an advantage particularly with a large number of metering devices with a lot of short-cycle data. The middleware can locally process and optimise the measurement values of the terminals combined into groups (terminal group EG). "Virtual households" and "virtual power stations" are formed on site and the flow of data to the applications (apps) is reduced. This data can then be processed much more easily by conventional load analysis applications with limited calculation methods.

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The middleware nodes are connected together via a communication network and communicate via an integrated network interface. In this way if necessary the data of all connected nodes are available everywhere. The middleware offers different internal

network interfaces, which are based both on Unicast (LabNet - TCP/IP) and on Multicast (LabPGM - PGM Pragmatic General Multicast).

5 The current and future state of the art in the area of smart grid/smart metering is the use of TCP/IP-based protocols. This is supported by EU-funded programmes. This includes all physical means with sufficient transmission speeds on the basis of TCP/IP. In this way short-cycle data capture can be achieved. It is irrelevant here whether IPv4 (internet Protocol Version 4) or IPv6 (internet Protocol Version 6) is used.

10 In order to uncouple the applications (apps) from the hardware, the middleware works directly with the respective protocol of the devices and provides the information for the applications (apps) in a general and standardised form. The middleware always brings the data transmission from the smart meter, from the applications (apps) or from a database via an interface to the transparent middleware level and controls the data
15 access.

On the whole middleware level there is a simple form of process variables adapted to use in the smart grid. Every type of digital meter and every application (app) has its own set of variables, which consists of a basic data set which is identical for all meters and
20 contains the necessary measurement values and commands. To perform clear device identification a variable set is identified, e.g. on the unique device ID or also an internal device number of the energy utility companies (EVU) and not by way of the varying communication network specific addresses.

25 With digital metering devices in the form of household meters there are generally two different types:

- a smart metering device (S-MG/smart meter)

30 This type of metering device has its own intelligence and can process the measured values in advance in order to carry out specific functions such as tariff control in the device. The function of ensuring the accuracy of the transmitted data by signature can be performed in smart meters for example.

- a lean metering device (L-MG/ L-meter)

This type of device is inexpensive and therefore only fulfils the minimum requirements
5 for tasks such as measuring, controlling and communication functions. The values are
captured and then transmitted in raw form. A signature for the data, if necessary, is only
possible to a very limited degree.

For connecting the metering devices and the software to the middleware for each
10 communication protocol or for each software interface there is a specific interface. The
interface to the digital metering device forms the connection to the devices, reads the
necessary data and activates commands. In order to relieve the applications (apps) the
interface functions completely self-sufficiently, communicates by means of the device-
specific protocols and independently updates the status of the variables. The
15 middleware provides all applications (apps) with an API (Application Programming
Interface). Domain-specific applications (apps) can be incorporated by means of an
additional dll (Dynamic Link Library). The communication of application (app) to
application (app) is provided by the middleware. For this purpose software agents can
be easily migrated which process tasks independently for communication between and
20 to the applications (apps).

With the use of tariff models as a product offered to customers, the individual
measurement values have to be assigned to corresponding tariff levels. This assignment
can be controlled by time, after consumption or after exceeding the load threshold. The
25 digital meters in the form of smart meters (S-MG) take over this task themselves.
Depending on the design of the device it is possible to have a specific number of
different tariff levels, for which there is a calibrated counter. The intelligence is thereby
installed in the meter and the tariff structures have to be completely defined and
transmitted by the middleware. If the digital meter or the sensor has no intelligence
30 (lean meter L-MG) and only supplies raw data, the middleware can take over the tariff
allocations, analyse the measurement values and put them in corresponding registers.

For separating the data from customers anonymisation may be performed in the middleware. In this case the measurement value (MW) captured by the digital meter (S-MG or L-MG) is cleaned in an anonymisation middleware service (A-MD) of identification features of the respective meter and provided as a raw value. Then general and statistical calculations can be performed with these values.

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The connection to individual devices is established and maintained automatically and transparently for use by the interface, so that all data is always available to all measuring devices according to the repetition rate of the reading and processing speed of the smart meters. If there is connection failure the communication is re-established.

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If the device to be read does not provide a time of day, the time stamp is added automatically in the middleware.

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If in the smart grid additional sensors (temperature, moisture etc.) are installed at node points, the latter can be easily connected to the middleware.

The middleware can take over the data logging in connection with a database and the associated interface. The logging is controlled by the interface to the database and works independently of other applications (apps).

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The basic data relevant to invoicing with the necessary values independent of the type of meter are saved after reading directly as raw values in a specially secured metering database. The latter is designed to be redundant and has to be able to hold the data for a longer period due to legal requirements. The data storage is performed automatically separately from the applications (apps) and functions without the applications (apps) having to be active. The storage and additional measurement value control is performed by a separate database interface. Databases with ODBC drivers are supported as standard.

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The communication is bidirectional for each interface, i.e. applications (apps), apart from reading the variables by setting specific variables in the middleware, can give commands to actuators and the commands are then translated by the corresponding

interface to the actuator. For requests in the smart grid this means for example controlling relay outputs or setting tariff tables or indicator signals. It is also possible to control power production plants.

5 An intelligent IP address management within the corresponding interface of the middleware controls the establishment of a connection to the individual devices by the use of smart meters with communications interfaces on the basis of TCP/IP. In such a network it links the dynamically distributed IP addresses from a DHCP (Dynamic Host Configuration Protocol) for example to the device IDs. Thus a newly installed device can
10 be immediately identified and set up automatically.

If devices do not support time synchronisation (for example via NTP Network Time Protocol) the middleware automatically synchronises the time with each connection to a smart meter. The accuracy of the time over the whole network is guaranteed by the
15 time synchronisation of the individual smart meters with one another or synchronisation with the host computer.

The requirement in the smart grid/smart meter is to ensure the predefined short capturing cycles during the transport of data from the sensors/smart meters to the
20 middleware level. Only if the data is available there first can all applications (apps) access at the same time and in parallel data in the form of variables and do not need to have knowledge of the actual transfer protocols.

An embodiment of the method is explained in the following with reference to the
25 drawings Fig. 2 to Fig. 5.

In the latter:

Fig. 2 shows an example of the structure of the method in overview with a combination of a smart meter and a lean meter.

30 Fig. 3 shows a detailed example of the structure of the method when using a smart meter.

Fig. 4 shows a detailed example of the structure of the method when using a lean meter.

Fig. 5 shows a detailed example of the structure of the method when using a smart meter with anonymisation of the measurement values.

Fig. 2 shows a combination in the overview of the two methods described in the following. The distributed middleware with the different intelligent middleware services (I-MD) (S-MD/ L-MD/ A-MD/ LO-MD/ A-MD) and the internal communication interface LabNet are shown. On the lower side is the known measuring and control level with smart meters (S-MG) and lean meters (L-MG). Both types of device are connected to the middleware and are used by the corresponding middleware services (L-MD or S-MD). As a rule the lean meters (L-MG) use the smart middleware services (S-MD) and the smart meters (S-MG) use the lean middleware services (L-MD). At the top is the application level with the applications (app 1 to app n). For the applications (apps) and the meters (MG) it is irrelevant which point of the middleware they are connected to. The local optimisation middleware service (LO-MD) processes for each data node a number of grouped terminals from the measuring and control level and provides the data to the application level in an optimised and reduced manner.

Fig. 3 shows a distributed intelligent middleware - here LabMap, which consists of at least two nodes. Said nodes are connected to one another via the integrated communication interface LabNet in the middleware. The connection is formed for example via LAN (Local Area Network) or WAN (Wide Area Network) - a network with wide area.

On the bottom left side of the middleware there is a smart meter (S-MG) which measures the consumption of electrical energy and produces a digital measurement value (MW) from the latter. As already defined, the smart meter (S-MG) has an integrated intelligence and can process the measurement value (MW) after detection. The measurement value (MW) is assigned to a tariff (TR), provided with the corresponding tariff indicators and signed by a signature function (SF). For the correct tariff allocations a tariff structure (TRS) needs to have been transmitted via the middleware. In this way there is thus a complete meter reading (ZW) prepared for transmission. The measurement value (MW) can also be subjected to other functions (sFu) in the meter.

The signed meter reading (ZW) is transmitted, which is then received by the middleware. The meter reading capture can be performed both by a PULL method (the middleware queries the meters (MG) individually) and also by a PUSH method (the smart meter sends its meter readings (ZW) periodically or controlled by events). In a lean middleware service (L-MD) the meter reading (ZW) is received after transmission, the signature of which is verified by a signature verification (SV) and after successful control is placed as a meter reading (ZW) in a handle (HD) (memory variable) with a clear number (HD No). In a raw value memory in the middleware the handles (HD) are ordered chronologically in the time sequence of the meter readings (ZW). Otherwise the most recently captured meter reading (ZW) is in a handle (HD). A handle (HD) with meter reading (ZW) is assigned to a specific meter (MG) and is clear on the whole middleware level. Via the connection of the individual middleware nodes by means of communication network LAN/ WAN and LabNet the handle (HD) with the meter reading (ZW) is available at each point in the middleware. Additional middleware services (MD) take on additional jobs and other functions (sFu) and can produce additional handles (HD). Each entity of the distributed middleware takes over the same basic tasks of measurement value acquisition and control. Further middleware services (MD) can be configured individually as required.

Applications (apps), such as the metering point management, SCADA systems or billing systems can access the middleware and either read the handles (HD) with the verified current meter readings (ZW), or the time sequence of the handles (HD) in the raw value memory. With continuous transparency and complete availability of the individual handles (HD) at each point of the middleware the applications (apps) can be connected everywhere.

Fig. 4 shows the same basic structure of the distributed middleware, only here there is a lean meter (L-MG) (L-meter) on the bottom right side. After measuring the electric consumption also a digital measurement value (MW) is produced. Due to missing or low intelligence the measurement value (MW) is now converted directly to a transferable meter reading (ZW). A signature function (SF) can be omitted in some circumstances, other functions (sFu) are implemented very rarely.

As with a smart meter (S-MG) now the meter reading (ZW) is transmitted. The latter then still has to be processed in the middleware. A smart middleware service (S-MD) performs the tasks that the smart meter(S-MD) would have taken over in the conversion
5 to a meter reading (ZW). The meter reading (ZW) is signature verified (SV), if available, and processed according to the valid tariff structure saved for the meter, in that it is saved in the corresponding handles (HD) or provided with indicators. All other properties of the middleware correspond to the description of Fig. 2.

10 Fig. 5 shows the option of data anonymisation in the intelligent middleware. The structure corresponds to the essential features of Fig. 2. A smart meter (S-MG) delivers a signed meter reading (ZW) with tariff and device information. The latter is processed (in addition to the lean middleware service (L-MD) or exclusively) by an anonymisation
15 middleware service (A-MD). Here the signature of the meter reading (ZW) is verified by the signature verification (SV) and separated by means of an anonymisation function (AF) from the device information. Then the digital measurement value (MW) is formed which is placed in a general handle (HD). The measurement value (MW) can be allocated to a tariff (TR) or represent a general total value. The handles (HD) with a clear number (HD No) are then always available with the current value or are ordered chronologically
20 in the raw value memory.

The connection of the application (app) to the middleware can be performed according to the following examples:

- 25
- the applications (apps) only operate online with the variables. They access the variables directly and save the necessary measurement values internally. However, this assumes that the application (app) can work as fast as the data flow in the system and receive and process the data in a short cycle (20 ms to 5 s) from the middleware.
- 30
- the applications (App) only operate offline with a database. They are asynchronous to the process and therefore need a persistent memory. This memory can be for example the raw data database or an extra database for this

purpose. The database is filled by the middleware by means of the associated interface.

- the applications (apps) operate simultaneously offline with a persistent memory and online with the middleware. This case is a combination of the two previous cases. The raw data is written by the middleware directly into a metering database and can be thus reached by the application (app). The short-cycle measurement values and commands are provided and are available.

10 **Task**

Short and long-cycle reading of actual and consumption data from smart meters and additional sensors in the power grid at intervals of 20 ms to 5 s.

15 **Representation of the measurement values on the middleware**

The middleware provides all information to the meters (measurement values, status, parameters, commands) in process variables, which can consist of four different data types: integers, reals, as a string or as a record. On the basis of the data type a variable has additional properties such as for example a clear ID, a name, a threshold value, a scaling factor, the unit (basic SI unit). In addition, the updating method of the variable can be set: manually, cyclically after a definable time interval or by changing the measurement values. Furthermore, the interface has to be selected, which communicates with the meters. The process variables can be used according to the configuration either for reading data from meters or for writing.

Each variable itself forms a unit and represents a measurement value in the configured properties. The interface communicates directly with the measurement values and relays them to the variables.

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In addition to the measurement values each variable has its own status, which belongs to each new measurement value. A status is for example "all OK" or "device not accessible", but also "threshold value exceeded".

The middleware has a programming interface, whereby for example a configuration software can create and configure the variables and applications can read the measurement values from the available variables.

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The data detection is performed by means of the socket select method, which makes it possible to address a large number of smart meters in parallel. Due to the simple structure of the variables and the use of interfaces for communicating with smart meters or sensors the middleware can also capture and also supply data particularly quickly compared to conventional smart meter reading systems (ZFA systems).

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Middleware in the network

Access to the variables of the middleware and via the network are controlled and secured by two mechanisms. On the one hand via the local properties of the variables and on the other hand by the property of network connection.

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Access control by the local definition of variables:

By means of the programming interface the variables of the middleware can be accessed asynchronously by different applications. Asynchronous means that it is possible to access the variables independently of the communication with the meters and independently of other applications. The access rights are thereby user-based. Each application registers as a user for access and then the middleware is known. The middleware creates dynamically a user list for the running time. Read access is always enabled by default for each user for all variables, however write access may be blocked by an application. Other applications can then no longer access said data.

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The access rights of the middleware can be divided into two classes:

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- shared access can be performed by each user (default)
- exclusive access can be currently performed exclusively by one user. This user can block the variables.

Only the user supervisor has all access. If an application with this user name logs in it can use all variables (even the blocked ones).

Access control by the network module and the network settings of the middleware:

5

Several distributed servers are used, which can be referred to as middleware nodes. At each node of the distributed system it is possible to implement an installation of the middleware. Each middleware node is defined by a configuration software with the required variables, depending on the requirements of the connected applications or the implemented middleware services. If a node requires the information in the variables of another node, then they can be mirrored by network variables from the source nodes and kept up-to-date. Here the locally defined access rights of the applications are considered from the user list. The network variables are used by the applications as local variables, synchronisation via the network is performed automatically by the middleware via the internal communication interface.

10

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If an application at a middleware node needs the data of a process variable at an additional middleware node, a network variable needs to be configured with the internal communication interface. For the configuration of the network variable firstly a connection is established to the source middleware node. Afterwards said middleware node can either be searched for the required variables or if the variable numbers are known the latter can be entered directly. Furthermore, access rights can be awarded for the network variables.

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The network variables between them of the middleware nodes have the following modes:

Read-only (ro) mode: the middleware node with the network variables is not able to change or update the source variables. Only the current statuses of the variables can be read.

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Read-write (rw) mode: the variables with the data are shared completely between the middleware nodes. Reading and writing of data is possible on all pages. A middleware node with network variables has full access to the source variables.

By means of a time synchronisation integrated into the middleware in the UTC time format the time stamps of different middleware nodes are automatically recalculated to the local time of the server. In this way an application can be used to check the data integrity and clarity over the whole network.

5

Redistribution of tasks in the middleware

The network variables are linked to one another logically and thus represent a middleware network. In this way if necessary tasks can be distributed to the middleware nodes. Thus for example a middleware node with connection to a metering database (database of the detected measurement data) can access the data of all variables of the meter (S-MG for smart meter/ L-MG for lean meter). Other middleware nodes can be responsible for the data collection of a number of measuring devices and for the provision of information in network variables.

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The use of middleware services is modular and the middleware nodes can if necessary use suitably configured services. The data required by different applications can be provided via the network to the corresponding middleware nodes.

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The specialisation of the middleware-nodes can be used for the redistribution of tasks in the middleware network.

Task

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The increasingly decentralised generation of power by means of renewable energies means that it is necessary to rethink the power grid structure and requires the highest level of energy efficiency to be maintained after making load flow optimisations that are as local as possible.

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Clustering of the middleware

The middleware can, independently of the given grid structures, by using the local optimisation middleware service (LO-MD) virtually reproduce the power grid for

example by calculations of known algorithms and can automatically carry out local load flow optimisations and calculations. Calculations can be made for example in virtual variables, which can be freely defined and can be programmed with an integrated script language. All data in other variables of the middleware is available there and the known algorithms of the load flow calculations can be executed.

A distributed middleware node can, if necessary, have access to locally or globally saved routing tables, which contain information about the logical distances between node points in the power grid. Said routing tables are filled with reference to known algorithms. With the data of the meters then the load flows along the routes can be calculated and reproduced in virtual variables. The virtual variables can access all other variables and external data, such as e.g. the routing tables, and perform the calculations.

Virtual variables can also contain specific calculation results (e.g. sums, averages or forecasts) and thus combine the data of meters. A combination by for example summation can be used both for the data capture (reduction of data for applications) and also for control applications (a command for a group).

The load flows can be controlled for example automatically connecting or disconnecting energy consumers via power switches (e.g. heating systems/ air-conditioning systems/ boilers) or switching on or off power generators by power switches (CHP/ solar panels/ wind turbines). The decisions for performing the control process can also be performed in virtual variables and with reference to calculation results. The middleware operates bidirectionally and can perform said actions locally automatically.

With the installation of middleware nodes in for example substations or other power grid node points the meters can be organised directly by means of the connected electric power lines by means of the grouping or clustering function of the middleware. The variables can thus be assigned in the middleware to corresponding groups.

The meter point designation which in the energy market makes it possible to clearly identify the meters of customers, can be used as identification of variables on the

middleware. Applications in which power providers can directly address the variables and the information contained there via said identification.

P A T E N T K R A V

1. Fremgangsmåde til fordelt, intelligent dataregistrering med kort cyklus og styring af et stort antal af målepunkter i overensstemmelse med kravene til et intelligent energiforsyningsnet, ved hvilken fremgangsmåde

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- der anvendes flere i energiforsyningsnettet fordelte servere, som tilsammen danner en middleware,
 - der ved hjælp af middlewaren under anvendelse af en middleware-grænseflade med kort cyklus registreres måleværdier (MW) fra digitale måleapparater og tællerværdier (ZW), og de digitale måleapparater såvel som
- 10
- yderligere sensorer og aktorer styres,
 - måleapparaterne er sammenfattet i grupper, som hver er tilordnet en server, måleværdierne (MW) tilordnes tarifynformationer (TR) i middlewaren, hvor middleware-grænsefladen er kompetent til tilvejebringelse af tællerværdierne (ZW) og viderebefordring af overordnede styresignaler, og hvor dataregistreringen med kort cyklus betyder en registrering af måleværdier i tidsintervaller
- 15
- på 20 ms til 5 s alt efter netstørrelse for fra 1000 til nogle 10000 slutapparater, og alt efter ledningsevnen af de digitale måleapparater,
 - måleværdierne (MW) og tællerværdierne (ZW) ved hjælp af signaturverifikation (SV) undergår en gyldighedsefterprøvning i middlewaren,
- 20
- der cyklisk tilvejebringes en afbildning af tilstanden af energiforsyningsnettet i lagervariable (HD) og et råværdilager i middlewaren, og at et tidstempel automatisk tilføjes,
 - måleværdierne (MW) i anonymiseret form sammenknyttes med en tælleridentifikation i middlewaren ved hjælp af interne middleware-tjenester (MD),
- 25
- der følger en anonymisering af tællerværdierne (ZW) ved erstatning af beskrivelsen af måleværdioprindelsen (f.eks. apparatidentifikation) ved hjælp af en anonymiserings-middleware-tjeneste (A-MD),
 - en middleware-tjeneste (MD) er kompetent til at sørge for en tilordning af måleværdierne (MW) til slutapparater, og en tilordning sørger for, at tællerværdien (ZW) af et slutapparat altid forbliver rekonstruerbar,
- 30
- dataregistreringen og styringen overtages af interne middleware-tjenester (MD) i middlewaren,
 - serverne er forbundet med hinanden over et kommunikationsnetværk, og kommunikerer via interne netværksgrænseflader, således at måleværdierne og tællerværdierne er til rådighed på hver server,
- 35
- kommunikationen med de digitale måleapparater følger efter en af et smartmåleapparat (S-MG) eller lean-måleapparat (L-MG) foregivet protokol og indsættes til kommunikationen af middleware-grænsefladen, hvor et smartmåleapparat (S-MG) besidder en intelligens og er udformet til forbehandling

ning af måleværdierne (MW), medens et lean-måleapparat (L-MG) ikke besidder nogen intelligens og kun er udformet til udlevering af ubearbejdede måleværdier (MW),

- 5 – hvor sammenknytningen af tællerværdier (ZW) og tarifinformationer (TR) for lean-måleapparater (L-MG) udføres ved hjælp af en middleware-tjeneste (S-MD),
- hvor sammenknytningen af tarifinformationer (TR) for smart-måleapparater (S-MG) sikres af apparatet, og
- 10 – hvor en yderligere middleware-tjeneste (L-MD) styrer en tilsvarende tarifstruktur (TRS) af apparatet, og overtager synkroniseringen af et integreret ur.

2. Fremgangsmåde ifølge krav 1, k e n d e t e g n e t ved, at til datasignering, i fald slutapparaterne stiller signaturfunktioner (SF) til rådighed, overtages signaturverifikationen (SV) af den respektive tilhørende middleware-tjeneste (L-MD, hhv. S-MD).

- 15 3. Fremgangsmåde ifølge krav 2, k e n d e t e g n e t ved, at middlewaren stiller de registrerede måleværdier (MW) til rådighed med kort cyklus, at hver måleværdi (MW) besidder et tidstempel, som genereres af middlewaren ved registreringen, hvor den aktuelle måleværdi (MW) og dens statusinformationer (f.eks. gyldighed, tidstempel) ved hjælp af en lagervariabel (HD) altid er til rådighed i middlewaren, og at måleværdierne (MW) ligeledes stilles kronologisk ordnet til rådighed i råværdilageret.

- 20 4. Fremgangsmåde ifølge ét af de foregående krav, k e n d e t e g n e t ved, at en fordeling af dataregistreringen og styringen realiseres over en intern kommunikationsgrænseflade af middlewaren baseret på gængse netværksprotokoller, såsom TCP/IP (Transmission Control Protocol/Internet Protocol) og PGM (Pragmatic General Multicast),
- 25 og at, alt efter konfiguration, alle data af de fordelte knudepunkter er til rådighed overalt.

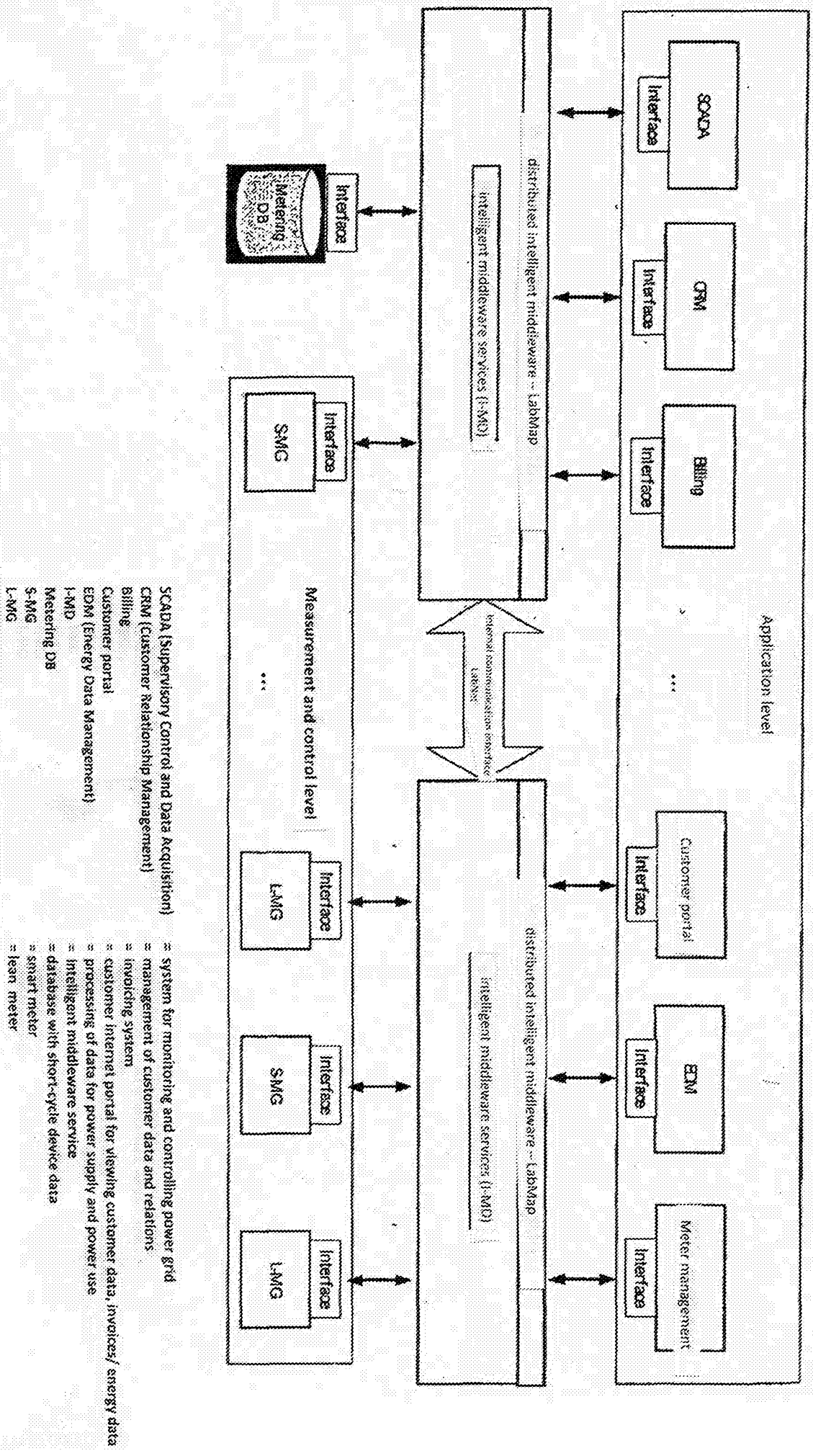
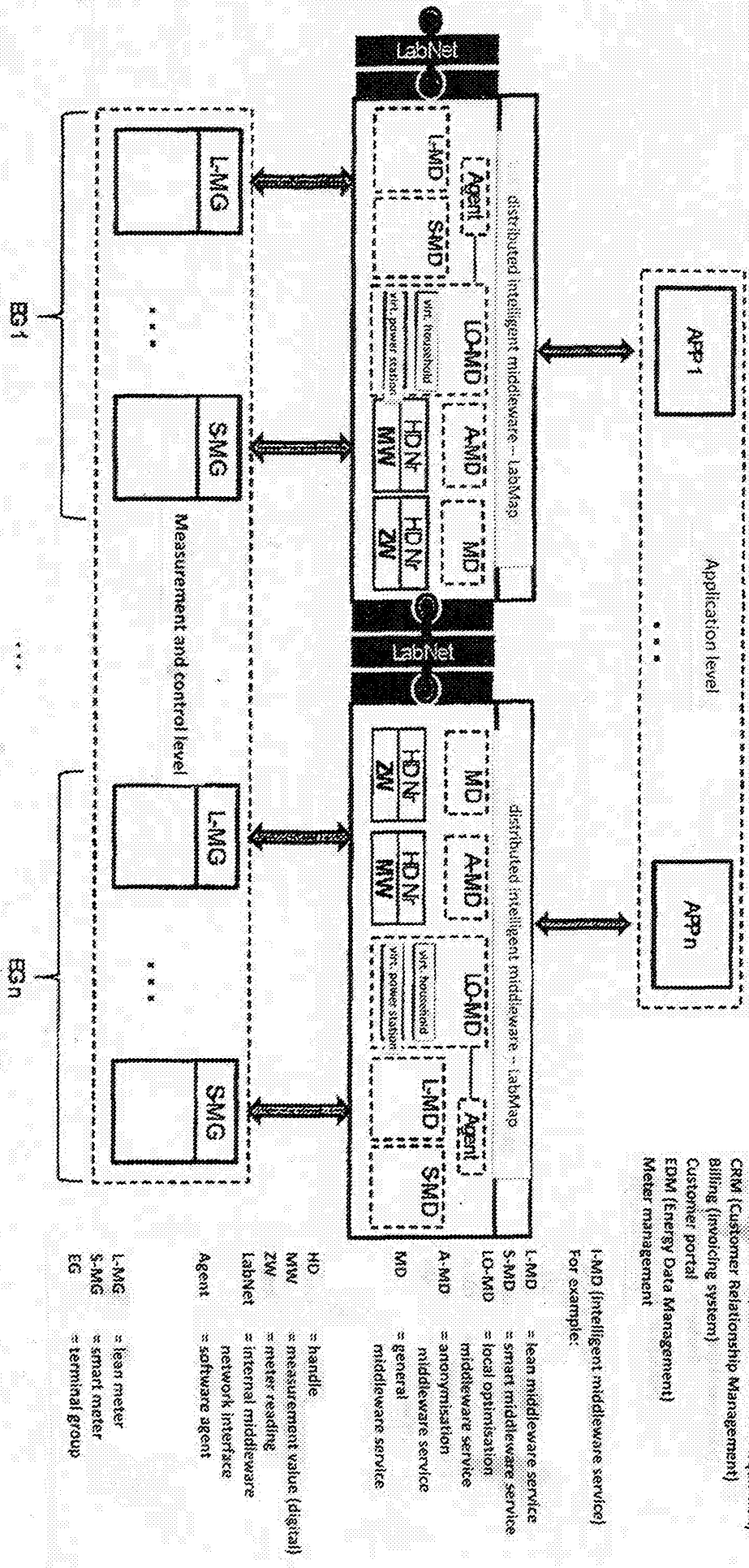


Fig. 1. Example of the structure of a system for use in a smart grid/ smart metering with distributed intelligent middleware

- = system for monitoring and controlling power grid
- = management of customer data and relations
- = invoicing system
- = customer internet portal for viewing customer data, invoices/ energy data
- = processing of data for power supply and power use
- = intelligent middleware service
- = database with short-cycle device data
- = smart meter
- = lean meter



APP 1 ... APP n = application e.g.
 SCADA (Supervisory Control and Data Acquisition)
 CRM (Customer Relationship Management)
 Billing (invoicing system)
 Customer portal
 EDM (Energy Data Management)
 Meter management

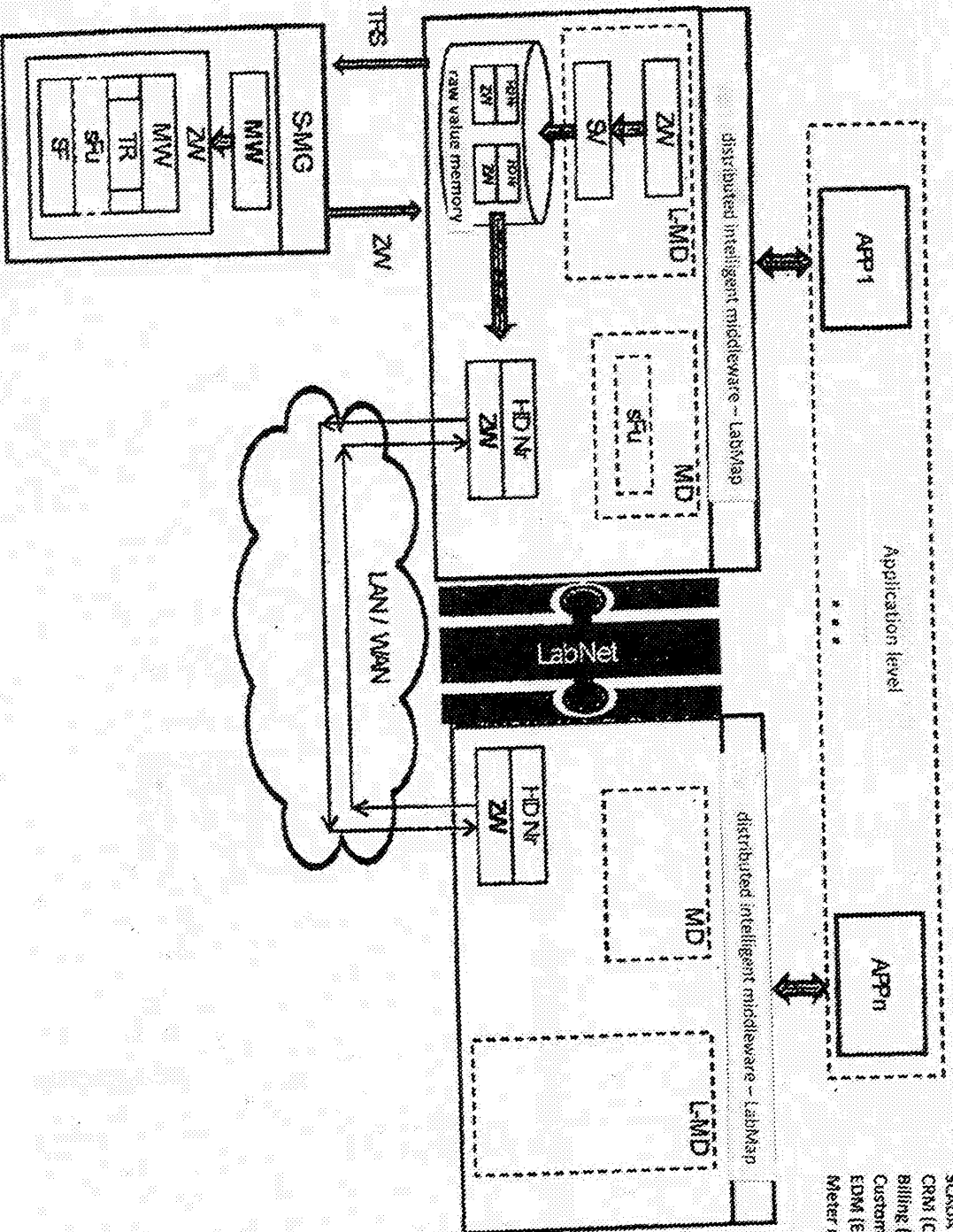
L-MID (intelligent middleware service)
 For example:

L-MID = lean middleware service
 S-MID = smart middleware service
 LO-MID = local optimisation middleware service
 A-MID = anonymisation middleware service
 MD = general middleware service

HD = handle
 MW = measurement value (digital)
 ZM = meter reading
 LabNet = internal middleware network interface
 Agent = software agent

L-MG = lean meter
 S-MG = smart meter
 EG = terminal group

Fig. 2: Example of the structure of the distributed middleware with a combination of a smart meter and a lean meter.

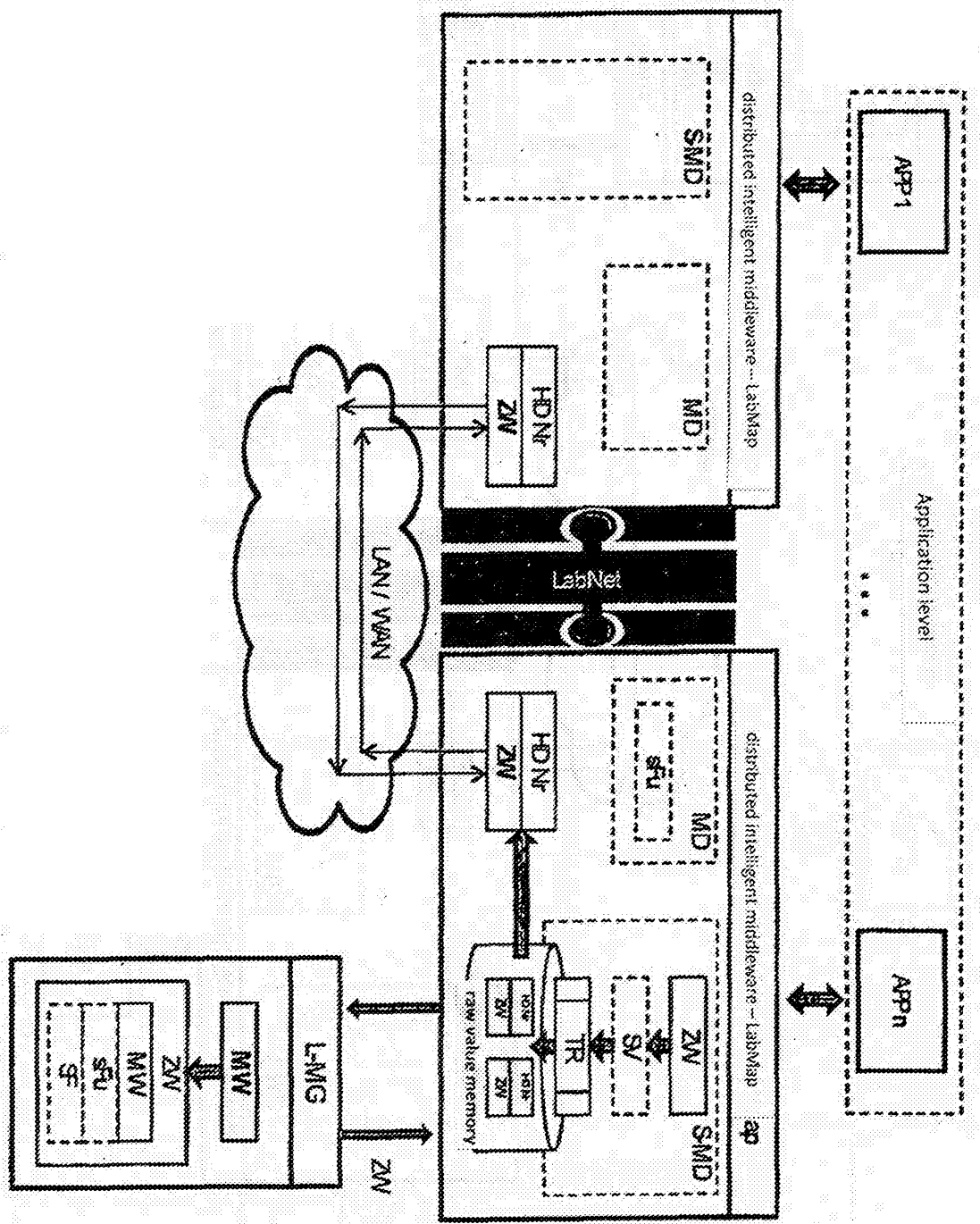


APP 1 ... APP n = application e.g.
 SCADA (Supervisory Control and Data Acquisition)
 CRM (Customer Relationship Management)
 Billing (invoicing system)
 Customer portal
 EDM (Energy Data Management)
 Meter management

L-MID = lean middleware service
 SV = signature verification
 HD = handle
 MID = middleware service
 TNS = tariff structure
 LabNet = internal middleware network interface
 LAN = local Area Network
 WAN = Wide Area Network

S-MG = smart meter
 M/W = measurement value (digital)
 Z/W = meter reading
 SFu = other functions
 SF = signature function

Fig. 3: Example of the structure of the distributed middleware when using a smart meter.



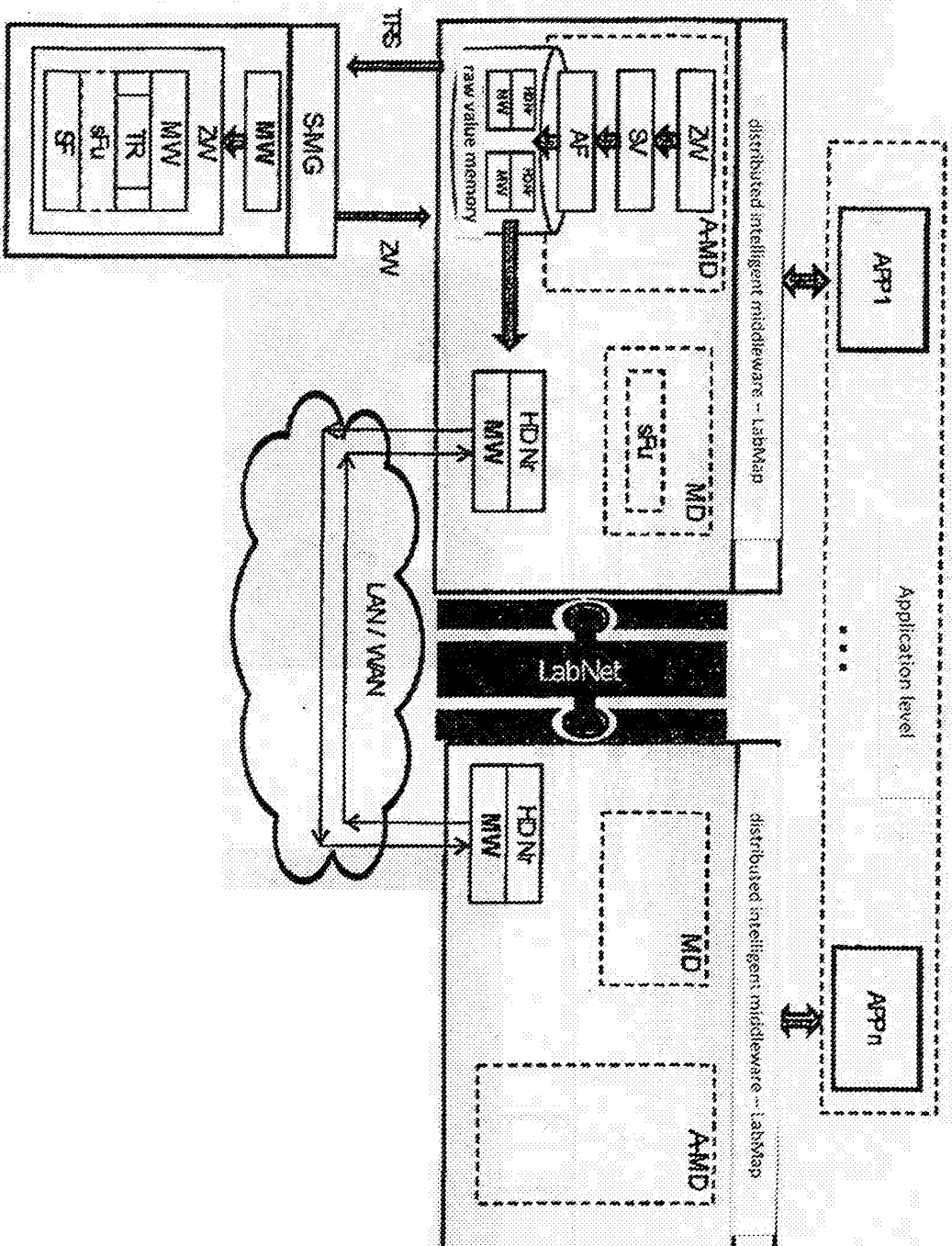
APP 1...APP n = application e.g.
 SCADA (Supervisory Control and Data Acquisition)
 CRM (Customer Relationship Management)
 Billing (invoicing system)
 Customer portal
 EDM (Energy Data Management)
 Meter management

S-MD = smart middleware service
 SV = signature verification
 TR = tariff
 HD = handle
 MD = middleware service

LabNet = internal middleware network interface
 LAN = Local Area Network
 WAN = Wide Area Network

L-MG = lean meter
 MW = measurement value (digital)
 ZM = meter reading
 sfu = other functions
 SF = signature function

Fig. 4: Example of the distributed middleware when using a lean meter.



APP 1 ... APP n = application e.g.
 SCADA (Supervisory Control and Data Acquisition)
 CRM (Customer Relationship Management)
 Billing (Invoicing system)
 Customer portal
 EDMS (Energy Data Management)
 Meter management

A-MID = anonymisation middleware service
 SV = signature verification
 AF = anonymisation function
 HD = handle
 MID = middleware service
 LabNet = internal middleware network interface
 LAN = Local Area Network
 WAN = Wide Area Network

S-MG = smart meter
 MW = measurement value (digital)
 ZV = meter reading
 SFU = other functions
 SF = signature function

Fig. 5: Example of the distributed middleware when using a smart meter with anonymisation of the measurement values

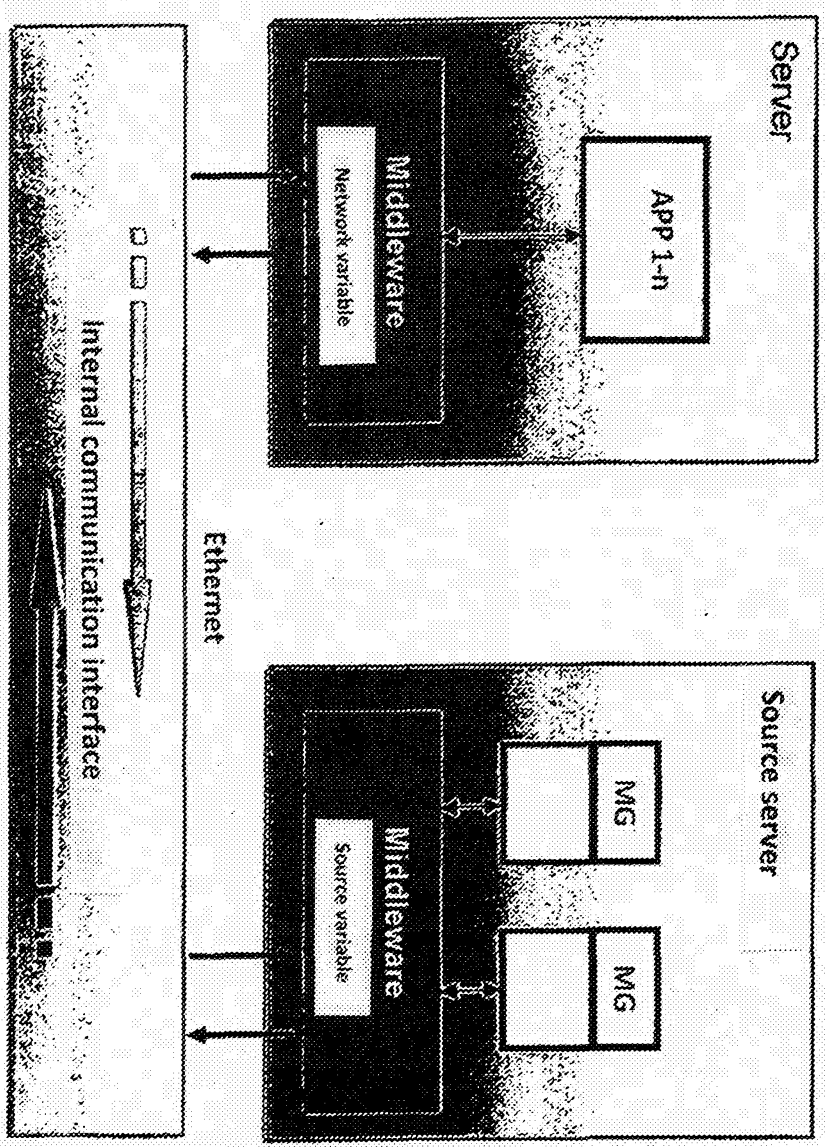


FIG. 6

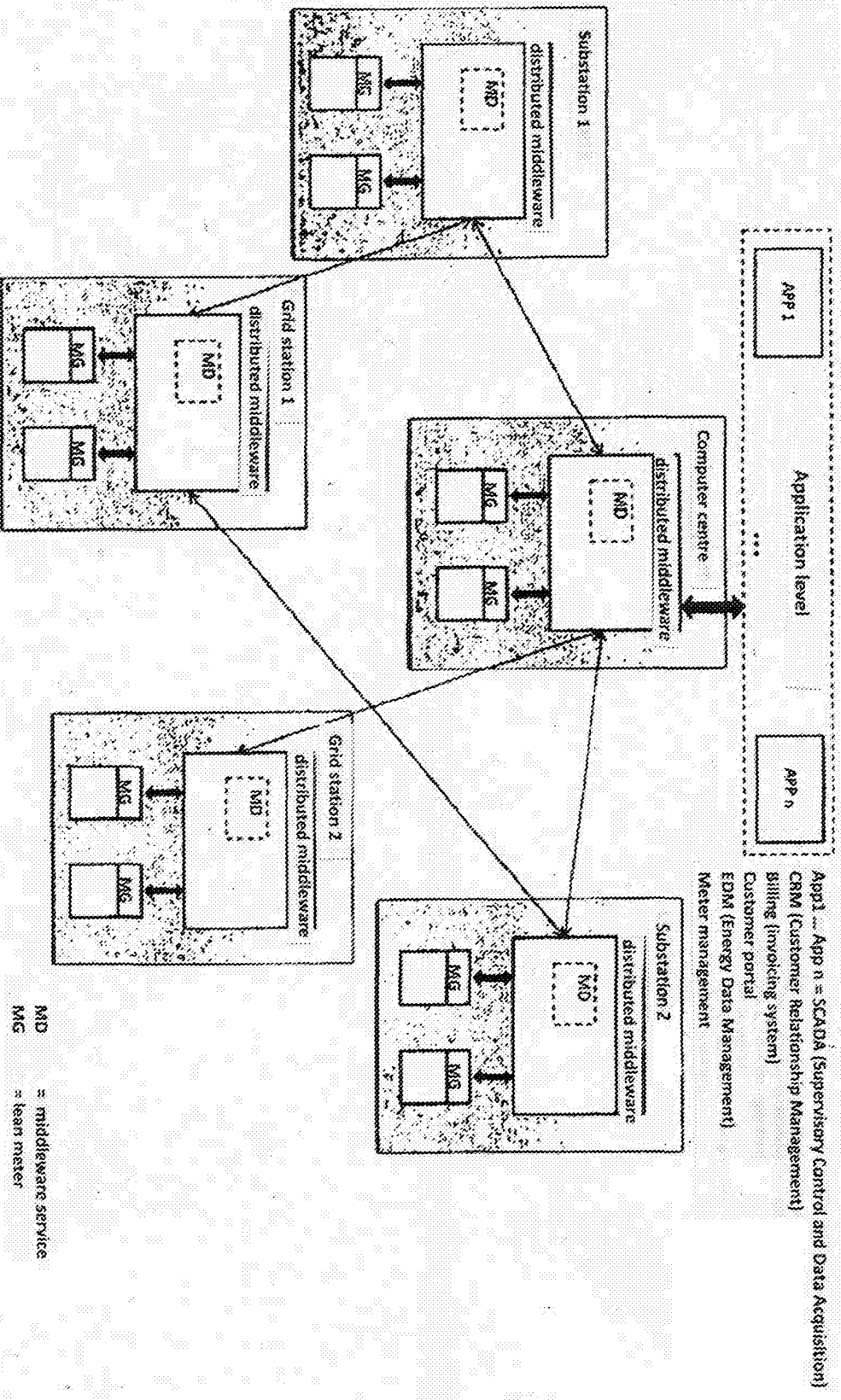


Fig. 7